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Summer phytoplankton in selected lakes of the East Suwałki Lakeland in relation to the chemical water parameters

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Abstract: The study covered a complex of 16 lakes of the East Suwałki Lakeland, distinguished by high differentiation of morphometric parameters determining their polymictic or dimictic character. In half of the lakes studied, the occurrence of summer water thermal stratification was observed. It strongly influenced the vertical qualitative and quantitative diversification of phytoplankton. The majority of the lakes studied were classified as eutrophic waters. Only lakes Szelment Wielki and Pejcze had the Carlson chlorophyll index at the boundary of mesoeutrophy. In the case of the majority of the lakes, the concordance of all the trophy indices was recorded. In 6 mesoeutrophic lakes, the character of water was only suggested by phytoplankton parameters.

Key words: phytoplankton, trophy indices, lakeland

Introduction

Summer phytoplankton is a very good indicator of lakes' trophic status (Hörnström 1981; Hutchinson 1967; Szeląg-Wasilewska et al. 1999; Reynolds et al. 2002; Szeląg-Wasilewska 2007; Dembowska 2011; Jaworska and Zdanowski 2011). The occurrence of certain phytoplankton species suggests a particular trophic status. In the case of dimictic lakes, the development of thermal layers determines the vertical variability of the composition of phytoplankton in relation to the vertical differentiation of light, oxygen, and nutritive conditions (Reynolds et al. 2002; Grabowska et al. 2006; Jekatierynczuk-Rudczyk et al. 2012). In fertile stratified lakes, oxygen deficits occur frequently in the hypolimnion or even metalimnion (Wojciechowska et al. 2004). Phytoplankton development depends on the presence of mineral and organic nitrogen, phosphorus, and carbon compounds (Reynolds et al. 2002). The aforementioned elements are used to calculate trophy indices (Carlson 1977; Dunalska 2011). In the case of deep stratified lakes, trophy indices are calculated based on various parameters, and may not be consistent, classifying the lakes to different trophic statuses (Hillbricht-Ilkowska and Wiśniewski 1994). The amount of phosphorus supplied to lakes from their direct catchments often exceeds the acceptable load even several times. This results in accelerated eutrophication (Hillbricht-Ilkowska 1994). Lakes located on rivers are supplied with an additional load of phosphorus inflowing from tributaries (Hillbricht-Ilkowska and Wiśniewski 1994). The symptom of water eutrophication is a decrease in the phytoplankton species diversity, and an increase in its biomass. The conditions of high phosphorus concentrations and simultaneous low nitrogen concentrations are well endured by cyanophytes, capable of the intake of nitrogen from the atmosphere (Bucka and Wilk-Woźniak 2005).

The studies on the northernmost complex of Polish lakes conducted so far have been mainly based on large lakes from areas under protection, as well as on physical and chemical water parameters and chlorophyll *a* concentration (Hillbricht-Ilkowska 1994). Data on the phytoplankton of lakes, particularly those with a smaller surface area, in the agricultural landscape of the Suwałki Region, are scarce.

In order to expand knowledge on the state of aquatic environments outside the boundaries of national and landscape parks, an attempt was under-taken to determine the composition of summer phytoplankton of 16 lakes of the East Suwałki Lakeland differing in the surface area and depth. Based on the chemical parameters of water and phytoplankton, the trophic status of the lakes studied was estimated.

Methods

Taking water samples for phycological, physical and chemical analyses was conducted between 20 and 21 July 2004. In all of the lakes studied, water samples were taken from the surface layer (0.5-1m), and in deeper stratified lakes additionally from the meta- and hypolimnion.

Measurements of water temperature, pH, electrolytic conductivity, and oxygen concentration and saturation were performed in the field by means of a Hydrolab sonde (USA). Secchi visibility (SD) was also measured. In the laboratory, the following were determined: orthophosphates (SRP), total phosphorus (TP) (Hermanowicz et al. 1976), dissolved and particle organic carbon (DOC, POC) (Zieliński and Górniak 1999), and chlorophyll *a* (Chl) concentrations (Lorenzen 1965; Nush 1980).

Shortly after phytoplankton samples were taken, they were preserved in Utermöhl liquid. The qualitative and quantitative analysis of phytoplankton was conducted by means of an Olympus BX-50 microscope. Up to 200 specimens were counted in each sample. Phytoplankton biomass was calculated based on the authors' own measurements of cells. Phytoplankton groups reaching the minimum of 50% of total phytoplankton biomass were recognised as the dominating groups.

In order to calculate trophy indices based on total phosphorus and chlorophyll *a* concentrations, Carlson's equations (1977) and Dunalska's equation (2011) were used, with the application of total organic carbon concentrations. The phytoplankton trophy index was calculated based on the biomass of indicator taxa from the epilimnion of the lakes in accordance with Hörnström's equation (1981). Trophy index values for particular taxa were adopted following Szeląg-Wasilewska (Szeląg-Wasilewska et al. 1999, 2007). Phytoplankton trophy index values were assigned to 6 trophic statuses (0.00-0.74 oligotrophy; 0.75-1.24 oligomesotrophy; 1.25-1.74 mesotrophy; 1.75-2.24 mesoeutrophy; 2.25-2.74 eutrophy; 2.75-3.00 strong eutrophy).

Study area

The study covered 16 postglacial lakes located in the East Suwałki Lakeland (NE Poland) in the catchment of the Szeszupa, Szelmentka, and Wiatrołuża Rivers (Fig. 1). The semi-natural landscape of the Lakeland is distinguished by high denivelations (up to 70 m) and the mosaic character of the terrain resulting from the mutual interweaving of small forest areas with cultivated fields and wetlands (Hillbricht-Ilkowska 2005). The diversity of landforms is accompanied by a mosaic of mineral soils, from carbonate and permeable pararendzinas to superficially acidified lessive soils on glacial tills. Floors of often closed-drainage depressions with smaller lakes are covered by deluvial soils or gleysols with small islands of organic soils. The area is distinguished by the shortest vegetation season in Poland and the lowest mean annual air temperatures. The average duration of the occurrence of ice cover on lakes is 90 days (Górniak 2000).

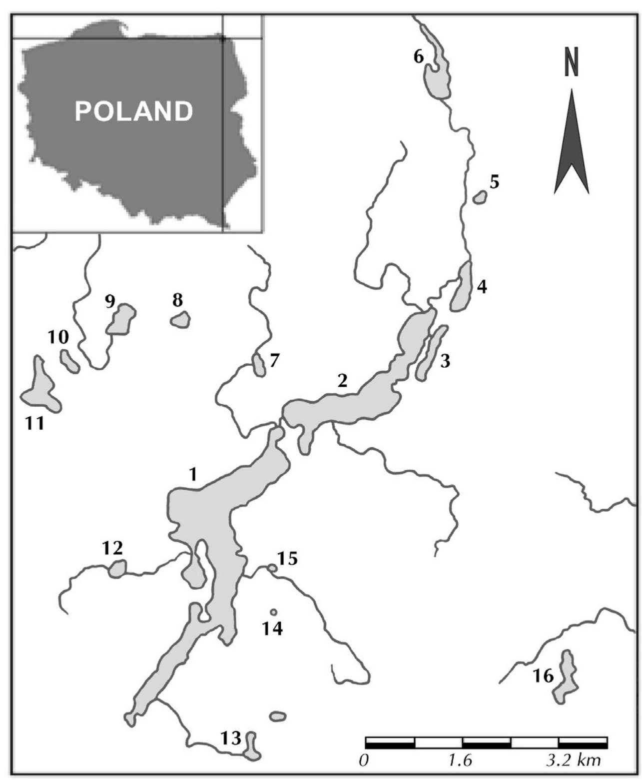

Fig. 1. Lakes studied: 1 – Lake Szelment Wielki, 2 – Lake Szelment Mały, 3 – Lake Jodel, 4 – Lake Ingiel, 5 – Lake Postawelek, 6 – Lake Kupowo, 7 – Lake Kozin, 8 – Lake Jałówek, 9 – Lake Jałowo, 10 – Lake Sumówek, 11 – Lake Sumowo, 12 – Lake Udryn, 13 – Lake Leszczewo, 14 – Lake Pejcze, 15 – Lake Staw Gielucha, 16 – Lake Grauże

The morphometric parameters of the 16 lakes are very varied (Table 1). In the summer period, thermal stratification developed in 8 of the lakes studied, and it was lacking in the remaining 8, which suggests their polymictic character. Oxygen deficits were observed during summer stratification in 6 lakes (Table 1).

Results

All of the lakes showed an alkaline reaction of their waters. The pH values varied from 7.23 to 8.43. The minimum was recorded for Lake Jałówek, and the maximum for Lake Kupowo. Water temperature in the surface water layer of the lakes always exceeded 21°C, reaching the highest value of 26.3°C in Lake Staw Gielucha. In the case of deep lakes, clear thermal stratification was observed. Water temperature at depths exceeding 10 m usually decreased to several Celsius degrees. In 5 stratified lakes (Lakes Kupowo, Szelment Mały, Sumowo, Jałowo, and Udryn), oxygen supersaturation (>100%) in the epilimnion was accompanied by its deficits in the meta- and hypolimnion. The worst oxygen conditions at the bottom occurred in Lakes Kupowo (0.0%) and Jałowo (1,6%).

Concentrations of phosphates and total phosphorus largely varied from 7.23 μg dm^{-3} to 47.0 μg dm^{-3} for SRP, and from 54.5 μg dm^{-3} to 150.6 μg dm^{-3} for TP. Mean concentrations of both of the parameters amounted to 14.2 μg dm^{-3} and 94.1μg dm^{-3}, respectively. The lowest concentrations of phosphates and total phosphorus were recorded in the surface layer of the lakes, and the highest in the hypolimnion. Concentrations of dissolved (DOC) and particulate (POC) organic carbon showed high variability between lakes. The lowest DOC and TOC concentrations were recorded in Lake Szelment Wielki, and the highest in Lake Kozin, and Lakes Staw Gielucha and Udryn (Table 2). In the case of DOC and TP, the differences were statistically significant.

In the case of chlorophyll *a* concentration, a wide range of concentrations was recorded from 5.77 μg dm^{-3} (Szelment Wielki) to 61.1 μg dm^{-3} (Lake Staw Gielucha). In stratified lakes, high variability of cholorophyll a concentration occurred in the lakes' thermal layers. Maximum chlorophyll *a* concentrations were most frequently observed in the metalimnion of the lakes. Only in the case of Lakes Sumowo and Jałowo, the highest chlorophyll *a* concentrations were recorded in the epilimnion.

In the 16 lakes of the East Suwałki Lakeland, the occurrence of 135 phytoplankton taxa was determined. They were represented by 8 algal groups: Cyanoprokaryota, Cryptophyta, Dinophyta, Euglenophyta, Bacillariophyceae, Chrysophyceae, Chlorophyceae, and Zygnemathophyceae.

Table 1. Description of 16 lakes of the East Suwałki Lakeland based on morphometric parameters of lakes and oxygen deficits in lakes

Lake	Area	Maximum depth	Volume	Oxygen deficit depth
	[ha]	[m]	[k m^3]	[m]
Kupowo	27	13.2	1625.2	≤5m
Ingiel	16	9.7	698.9	
Jodel	12.5	4.7	427.5	
Szelment Mały	168	28.5	12577.3	≤15m
Szelment Wieki	334	45	53492.0	
Postawelek	2.5	3.5	37.5	
Sumowo	30	8	661.5	≤5m
Sumówek	7.5	5	112.5	
Jałowo	15.2	15.5	854.3	≤11m
Jałówek	5.8	<5	116.0	≤2m
Kozin	4.6	<5	69.0	
Udryn	6.4	6.1	159.1	≤2m
Staw Gielucha	0.5	<5	7.5	
Pejcze	0.6	<5	9.0	
Leszczewo	7.6	5	190.2	
Grauże	13	8	520.0	

Table 2. Mean values of physical and chemical parameters of water from the epi- and metalimnion of the studied lakes of the East Suwałki Lakeland in July 2004; ns – not specified; tb – to bottom

Lake	SD	pH	EC	Chl *a*	SRP	TP	DOC	POC	SiO_3	NO_3
	[m]		[µS cm^{-1}]		[µg dm^{-3}]			[mg dm^{-3}]		[µg N dm^{-3}]
Kupowo	1.1	7.95	363.0	21.3	27.9	80.9	15.4	7.5	1.47	215.9
Ingiel	2.1	8.21	374.0	41.5	10.4	62.3	13.0	8.1	0.72	572.7
Jodel	0.65	8.12	418.5	59.7	10.7	78.4	21.0	20.4	2.97	54.2
Szelment Mały	3.1	8.12	374.0	16.5	11.0	92.7	12.7	3.7	0.58	793.6
Szelment Wielki	2.6	8.12	328.5	7.8	10.9	56.8	7.9	2.7	0.89	235.0
Postawelek	0.8	8.03	446.0	44.3	13.7	118.8	20.2	5.1	2.16	91.2
Sumowo	1.7	7.84	269.0	34.0	14.2	96.1	15.7	4.7	0.25	222.1
Sumówek	tb	8.16	230.0	15.0	23.1	114.3	16.6	5.5	1.31	49.0
Jałowo	2.2	7.86	246.5	25.5	12.9	97.0	11.0	2.2	0.41	50.3
Jałówek	2.6	7.47	209.1	34.8	10.8	81.0	20.7	1.4	0.51	36.1
Kozin	tb	7.68	375.0	30.2	14.9	90.0	52.5	6.7	0.81	234.7
Udryn	1.75	7.36	293.5	47.1	8.9	113.7	32.5	2.5	0.65	63.1
Staw Gielucha	ns	7.94	551.0	61.1	12.9	141.2	36.9	5.0	0.33	51.3
Pejcze	ns	7.91	368.0	7.6	13.1	121.1	11.2	2.8	0.96	57.7
Leszczewo	ns	7.96	408.0	57.0	10.0	74.4	27.6	3.8	0.86	53.8
Grauże	ns	8.07	346.0	29.8	10.4	82.2	12.4	5.2	0.87	51.2

The highest diversity was recorded among chlorophytes (46) and diatoms (28), and the lowest among chrysophytes (3). The highest number of taxa was identified in Lake Sumowo (49), and the lowest in Lake Grauże (18) (Fig. 2).

The values of total phytoplankton biomass (PB) for the 16 lakes varied from 0.15 mg dm^{-3} to 23.12 mg dm^{-3}, but in the majority of lakes it did not exceed 3 mg dm^{-3} (Fig. 3A, 4A). Higher PB values were recorded in stratified than in polymictic lakes (Fig. 3A, 4A). In 4 stratified lakes (Ingiel, Jodel, Sumowo, and Szelment Wielki), an increase in PB along with depth of lakes was observed, and its decrease was recorded in only 2 lakes (Kupowo and Udryn). In 2 Lakes (Szelment Mały and Jałowo), the lowest PB values were determined in the metalimnion (Fig. 4A).

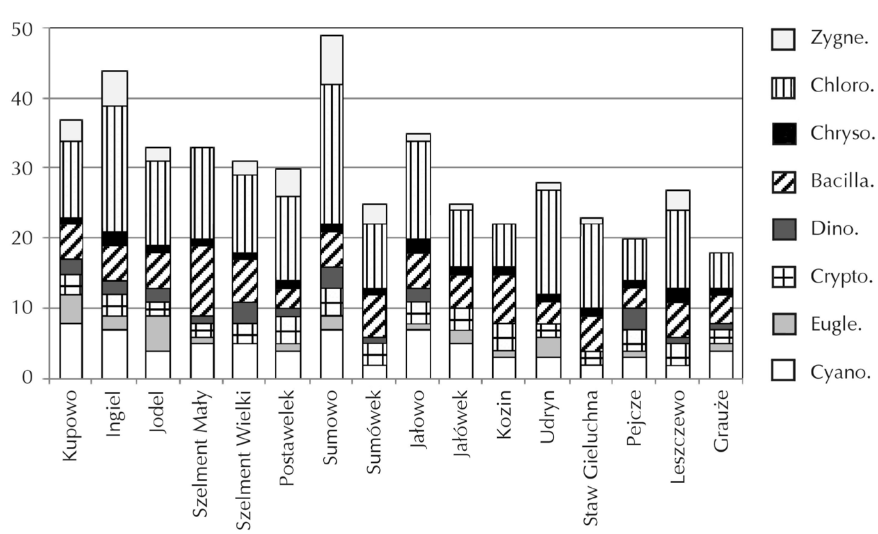

Fig. 2. Number of phytoplankton taxa in 16 lakes of the East Suwałki Lakeland

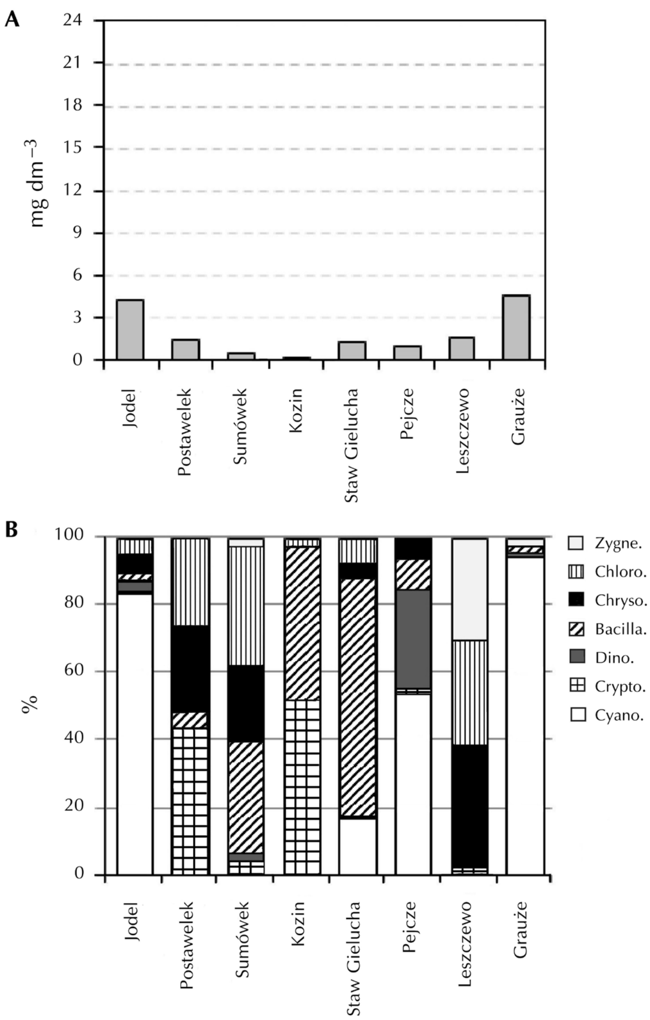

Fig. 3. Total phytoplankton biomass (A) and proportion of groups in total phytoplankton biomass (B) in 8 non-stratified lakes of the East Suwałki Lakeland

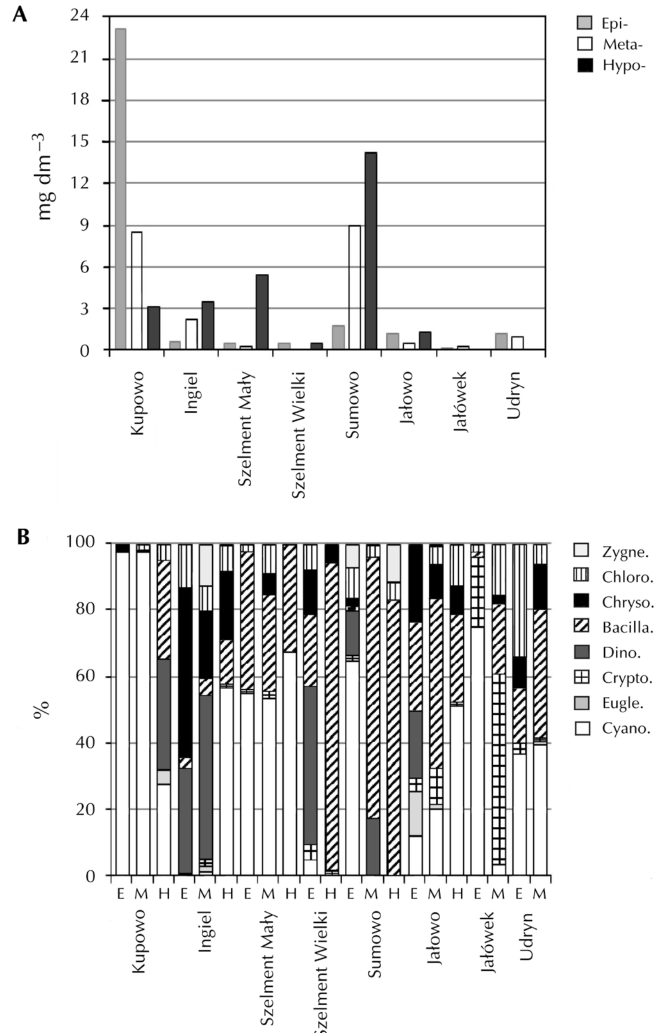

Fig. 4. Total phytoplankton biomass (A) and proportion of groups in total phytoplankton biomass (B) in selected layers (epi-, meta-, and hypolimnion) in 8 stratified lakes of the East Suwałki Lakeland

In 5 stratified lakes, in at least one of the layers studied, PB was dominated by cyanophytes (Kupowo, Ingiel, Szelment Mały, Sumowo, and Jałowo), in 2 by diatoms (Szelment Wielki and Sumowo), and in 1 by cryptophytes (Jałówek) (Fig. 4B). Among cyanophytes, the highest biomass was reached by filamentous (*Pseudanabaena limnetica*, *Pseudanabaena* sp.) or colonial forms (*Microcystis* spp.). Diatoms were mainly represented by centric forms from genus *Cyclotella* (*Cyclotella* spp., C. *meneghiniana*). The predomination of dinoflagellates was only determined in the metalimnion of Lake Ingiel (*Peridinium* sp.) and the epilimnion of Lake Szelment Wielki (*Ceratium hirundinella*), and of chrysophytes (*Dinobryon divergens*) in the epilimnion of Lake Ingiel (Table 3). In the case of non-stratified lakes, in three of them the definite predomination of filamentous cyanophytes was recorded (Jodel and Grauże – *Pseudanabaena limnetica*, *Pseudanabaena* sp., Pejcze - *Aphanizomenon flos-aquae*), and in one (Lake Staw Gielucha) the predomination of *Cyclotella* spp. In the remaining lakes, the co-domination of 2 (Kozin) or 3 (Postawelek, Sumówek, Leszczewo) algal groups was determined (Fig. 3B, Table 3).

The trophy index values based on total phosphorus (TSI_{TP}), chlorophyll *a* (TSI_{Chl}), and total organic carbon (TSI_{TOC}) concentrations varied from 50.5 to 84.7 (Table 4). Most often the highest values of TSI were recorded to TP or TOC. The lowest TSI_{TP}

Table 3. The most important taxa in terms of proportion of phytoplankton biomass (%B) in the epilimnion of 8 non-stratified and 8 stratified lakes in July 2004

Lake	Taxa	%B
Non-stratified lakes		
Jodel	*Pseudanabaena* sp.	83.8
Postawelek	*Cryptomonas* spp. *Dinobryon divergens*	43.3 25.4
Sumówek	*Oocystis lacustris* *Dinobryon divergens*	25.8 23.3
Kozin	*Cryptomonas ovata* *Cryptomonas rostatiformis* *Navicula* sp.	22.6 19.4 19.4
Staw Gielucha	*Cyclotella* sp. *Microcystis* sp.	71.0 16.8
Pejcze	*Aphanizomenon flos-aquae* *Ceratium hirundinella*	53.6 18.3
Leszczewo	*Dinobryon divergens* *Cosmarium pachydermum* *Staurastrum tetracerum*	35.9 19.5 10.7
Grauże	*Pseudanabaena limnetica* *Pseudanabaena* sp.	90.3
Stratified lakes		
Kupowo	*Pseudanabaena limnetica* *Pseudanabaena* sp.	97.5
Ingiel	*Dinobryon divergens* *Peridinium* sp.	52.7 31.4
Szelment Mały	*Microcystis* spp. *Fragilaria ulna*	54.8 31.8
Szelment Wielki	*Ceratium hirundinella* *Cyclotella* sp.	48.2 21.7
Sumowo	*Microcystis* spp.	64.5
Jałowo	*Cyclotella* sp. *Dinobryon divergens* *Peridinium* sp.	26.7 22.5 20.5
Jałówek	*Microcystis* spp.	73.8
Udryn	*Spirulina* sp.	36.0

and TSI_{TOC} were noted for Lake Szelment Wielki while TSI_{Chl} for Lake Pejcze. Only in the case of Lake Staw Gielucha did all indexes exceed 70. The phytoplankton index (TI_{PB}) varied from 1.78 to 2.75 (Table 4). The highest index was determined for Lake Kupowo. No phytoplankton index was determined for Lake Kozin, because the phytoplankton lacked indicator organisms.

Discussion

In connection with the high diversification of the morphometric parameters of the lakes, they are distinguished by a different trophic status. In most cases the trophy index values based on total phosphorus, chlorophyll *a* (Carlson 1977), and total organic carbon concentrations (Dunalska 2011) varied from 50 to 70. This suggests the mesoeutrophic or eutrophic status of the waters. In the case of 7 lakes, all of the indices were within that range. In the 12 remaining lakes, at least one of the indices exceeded the threshold of 70, ascribed to hypertrophy. The highest TSI_{TOC} value (84.7) was calculated for Lake Kozin. High TSI_{TOC} values are determined by the inflow of organic matter from the catchment, in the case of Lake Kozin introduced to the lake through a melioration ditch. The minimum values of the index, at the boundary of meso- and eutrophy, were recorded for TSI_{Chl} (Pejcze – 50.5 and Szelment Wielki – 50.8). The mesotrophic character of Lake Szelment Wielki is also confirmed by lack of oxygen deficits at the bottom. In 6 lakes, oxygen deficits were observed during summer stratification. The worst situation concerned Lakes Jałówek and Udryn, where oxygen depletion already occurred at a depth of 2 m (Table 1).

Only in the case of TSI_{TOC} and TSI_{Chl} was a statistically significant correlation determined ($r_{Spearman}$ =0.829, p=0.002). Lack of correlation between the remaining indices is surprising. According to Hillbricht-Ilkowska (1994), the incoherence of TSI indices based on TP, SD, and chlorophyll *a* is particularly visible in the case of deep dimictic lakes.

In the case of 4 lakes (Szelment Wielki, Szelment Mały, Ingiel, and Kupowo), Carlson's trophy index values from the years 1983-1985 (Hillbricht-Ilkowska, Wiśniewski 1994) and 2004 were compared (Table 5). In the majority of cases, an increase in the trophy index values was observed. Only for Lakes Ingiel and Kupowo were substantial decreases in TSI_{TP} determined, and for Lakes Ingiel and Szelment, decreases in phytoplankton biomass (Table 4, 5). In both of the study periods, the lowest trophy occurred in Lake Szelment Wielki, although in the 1990's, the actual TP load inflowing to the lake from the direct catchment according to the criteria by Vollenweider (1976) exceeded the acceptable load approximately 4 times (Hillbricht-Ilkowska 1994). In the case of one of the currently most eutrophicated lakes, namely Lake Kupowo, the situation was the opposite. The actual load of TP inflowing into the lake from the direct catchment dominated by agricultural land was 1.5 times lower than the acceptable load. In both periods, however, the highest phytoplankton biomass was recorded in the lake.

Table 4. Trophy indices calculated based on concentrations of chlorophyll (TSI_{Chl}), total phosphorus (TSI_{TP}), total organic carbon (TSI_{TOC}), and phytoplankton biomass (TI_{PB}); Kozin – lack of indicator organisms

Lake	TSI_{TOC}	TSI_{TP}	TSI_{Chl}	$TSI_{TP\text{-}Chl}$	TI_{PB}
Kupowo	69.8	67.5	60.6	64.1	2.75
Ingiel	68.5	63.7	67.2	65.4	2.05
Jodel	79.1	67.1	70.7	68.9	2.30
Szelment Mały	64.5	69.5	58.1	63.8	2.50
Szelment Wielki	57.7	62.4	50.8	56.6	1.96
Postawelek	71.3	73.0	67.8	70.4	2.06
Sumowo	67.9	70.0	65.2	67.6	2.27
Sumówek	69.2	72.5	57.1	64.8	1.78
Jałowo	61.1	70.1	62.4	66.3	2.60
Jałówek	69.2	67.5	65.4	66.5	2.50
Kozin	84.7	69.0	64.0	66.5	ns
Udryn	76.4	72.4	68.4	70.4	2.66
Staw Gielucha	79.3	75.5	71.0	73.2	2.00
Pejcze	62.0	73.3	50.5	61.9	2.10
Leszczewo	74.7	66.3	70.3	68.3	2.35
Grauże	65.6	67.7	63.9	65.8	2.54

Table 5. Comparison of summer total phytoplankton biomass and TSI (Carlson 1977) from the years 1983-1985 (following Hillbricht-Ilkowska and Wiśniewski 1994) and 2004

Lake	1983-1985				2004			
	Biomass [mg dm^{-3}]	TSI_{TP}	TSI_{Chl}	$TSI_{TP\text{-}Chl}$	Biomass [mg dm^{-3}]	TSI_{TP}	TSI_{Chl}	$TSI_{TP\text{-}Chl}$
Kupowo	4.7	76	60	68	23.1	67.5	60.6	64.1
Ingiel	5.0	83	54	68.5	0.59	63.7	67.2	65.4
Szelment Mały	1.3	65	49	57	0.48	69.5	58.1	63.8
Szelment Wielki	0.5	54	48	51	0.47	62.4	50.8	56.6

The phytoplankton index values determined in the study are typical of mesotrophy, eutrophy, and strong eutrophy. The highest number of lakes was classified as eutrophic ones. The most numerous group in unclassified Lake Kozin were cryptophytes, considered as an algal group with wide tolerance of environmental conditions (Reynolds et al. 2002). Mesoeutrophy distinguished 3 shallow non-stratified lakes, Lake Sumówek (1.78), Lake Staw Gielucha (2.0), and Pejcze (2.1), as well as only one large stratified lake, namely Szelment Wielki (1.96). In the case of Lake Szelment Wielki, high conformity of indices calculated based on physical and chemical water parameters and phytoplankton was determined. The highest trophy occurred in the case of lakes with clear dominance of cyanophytes (Kupowo, Udryn, Grauże, and Jałowo), commonly recognised as indicators of high trophic status of waters (Reynolds et al. 2002; Szeląg-Wasilewska et al.1999, 2007; Dembowska 2011, Jaworska and Zdanowski 2011). Among the trophy indices analysed, the lowest values corresponding to mesoeutrophy were only recorded for the phytoplankton index and Carlson's TSI_{Chl} (Table 4 and 5). It is possible that in spite of high concentrations of phosphates and total phosphorus in the surface layer of the lakes, not all of it is available to phytoplankton. A similar correlation was observed by Hillbricht-Ilkowska (1994) in lakes of the Suwałki Landscape Park and its buffer zone. Part of phosphorus may be unavailable for pelagic producers due to its binding with mineral particles of allo- and autochthonic origin (Hillbricht-Ilkowska 1994), or organic complexes (Górniak 1996).

Also other unpublished data of the authors for lakes of the Suwałki Lakeland suggest the possibility of occurrence in small lakes located in closed-drainage agricultural areas of periodical argillotrophy induced by periodical supply from the catchment of mineral colloids from clayey soils directly to the lake. High slope inclinations and spring or summer activation of erosion of cultivated soils after intensive precipitation can result in strong sorption of the phosphorus present in water by loamy soil particles supplied to lakes.

The lakes of the East Suwałki Lakeland had similar phytoplankton composition as the lakes of the Suwałki Landscape Park (Grabowska et al. 2006; Jekatierynczuk-Rudczyk et al. 2012). In both groups of the lakes compared, those most eutrophicated ones were distinguished by the predominance of cyanophytes (>50% PB) from orders Nostocales (*Aphanizomenon*, *Anabaena*), Oscillatoriales (*Pseudanabaena*, *Oscillatoria*), or Chroococcales (*Microcystis*, *Woronichinia*, *Merismopedia, Spirulina*). In lakes with the lowest trophy, the highest proportion of the phytoplankton biomass was reached by centric diatoms.

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